Mem. Qd Mus. **20**(1): 143–61, [1980].

THE ESTUARINE MACROBENTHOS OF THE CALLIOPE RIVER AND AUCKLAND CREEK, QUEENSLAND

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ABSTRACT

Quantitative benthic sampling in the Calliope River and Auckland Creek has been conducted at approximately 3 monthly intervals since November 1974 at 11 transects, each with 5 stations (55 sites). In September 1976 power generation commenced, using the estuary for thermal discharge. The data to August 1976 — the 'pre-thermal' situation — are intended to serve as the baseline for comparison with the 'post-thermal' situation. The 'pre-thermal' data are analysed here. A total of 263 taxa were found comprising 15 species of seagrasses and algae, 75 species of polychaetes, 51 species of molluscs, 91 species of crustaceans and 30 species belonging to other phyla. Of these species, those represented by less than 5 individuals, and those occurring in less than 2 sites or times, were not considered further. The remaining 72 species (representing 88.7% of all individuals collected) were classified into site-, time-, and species-groups using the 'Bray-Curtis' dissimilarily measure, followed by group-average sorting. Nine site-groups were accepted; these showed good topographic coherence and they could be characterized by their depths, substrate types, and position in the river. Classification into species-groups showed that many species were scattered throughout various sites, and on the basis of the pseudo-F test, only 39 species conformed to the site groups. Species classification using species-occurrences within the already established site-groups, gave 14 species-groups which characterize by their absence or presence, the various site-groups. Classification into time-groups showed that intertime dissimilarities are high, indicating that either sampling times were too distantly spaced, or alternately that seasonal differences overlie a non-seasonal trend. Cyclical analysis of summated species data identified a non-cyclic and a cyclic component with a period of approximately 12 months. A recolonization model has been proposed to describe these data; it is postulated that the intense flooding of December/January 1974 led to the removal of the benthos and that species reappearance was more or less linear over a period of 29 months, while the number of individuals of all species increased logarithmically. When comparisons with the 'post-thermal' fauna are made, it will be essential to allow for this recovery when assessing the thermal effects.

The utilization of estuaries as heat-sinks for electricity generating plants has stimulated considerable overseas interest in the effects of elevated temperatures on estuarine biotas (Naylor 1965, Thorhaug et al. 1973, Young and Frame 1976). In Queensland, several estuaries are affected by thermal discharges (e.g. Brisbane R., Burrum R., Ross R.) but there are no studies on the effects of elevated temperatures on estuarine biotas. As part of a general investigation into the benthic organisms of Port Curtis, the Calliope River and Auckland Creek are under study. The investigation of the macrobenthos of Port Curtis has now been terminated and an account of these data has been given (Stephenson et al. 1979).

Quantitative benthic sampling in the Calliope River and Auckland Creek has been conducted at approximately 3 monthly intervals since November 1974 at 11 transects, each with 5 stations (55 sites). With power generation commencing in September 1976, the results obtained from November 1974 to August 1976 — the 'pre-thermal' situation — are intended to constitute the baseline for comparison with the 'post-thermal' situation, and an analysis of these 'pre-thermal' results is given below.

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THE STUDY AREA

The study area (Fig. 1) comprises the Calliope River and Auckland Creek, both of which flow into Port Curtis, a semi-enclosed bay whose outer barrier consists of Facing and Curtis Islands.

Climatically, the area is sub-tropical with a mean annual rainfall of 944 mm, of which approximately 50% falls from December to February. Rainfall data, together with other meteorological and hydrological data are summarized in Table 1. Temperature, salinity and dissolved oxygen data for the Calliope River opposite the power station has been compiled from

TABLE 1: MEAN MONTHLY METEOROLOGICAL AND HYDROLOGICAL DATA FOR GLADSTONE AND CALLIOPE RIVER

Month	Mean Daily Temperature* (°C) Min/Max	Rainfall/Raindays* (mm)	Evaporation* (mm)	Humidity* (%) 9 a.m./3 p.m.	Radiation** ($MJ/m^2/day$)	Mean River Discharge*** (megalitres)
January	31·1/22·2	190/20	206	70/63	24·7	21,695
February	30·9/22·0	153/15	172	71/63	23·5	68,342
March	30·1/21·1	90/10	177	71/61	20·9	48,479
April	28·5/19·3	35/ 7	150	69/59	19·2	6,480
May	25·5/16·4	50/ 5	114	70/57	15·8	6,964
June	23·2/14·2	40/ 6	96	69/55	14·4	4,666
July	22·6/12·9	37/ 7	102	66/51	15·4	5,537
August	24·1/14·1	33/ 7	113	67/53	17·5	2,009
September	26·4/16·1	21/ 5	149	62/55	21·8	726
October	28·7/18·6	63/ 6	183	61/58	23·4	2,009
November	30·2/20·4	82/11	189	63/61	25·5	778
December	30·9/21·5	150/ 9	202	66/62	24·5	18,213
Annual	27·7/18·2	944/108	1855	67/58	20·5	185,718

* Supplied by Bureau of Meteorology
** from Paltridge and Proctor (1976)
*** Supplied by Water Resources Council of Queensland from 'Castlehope', 33 km upstream of mouth.

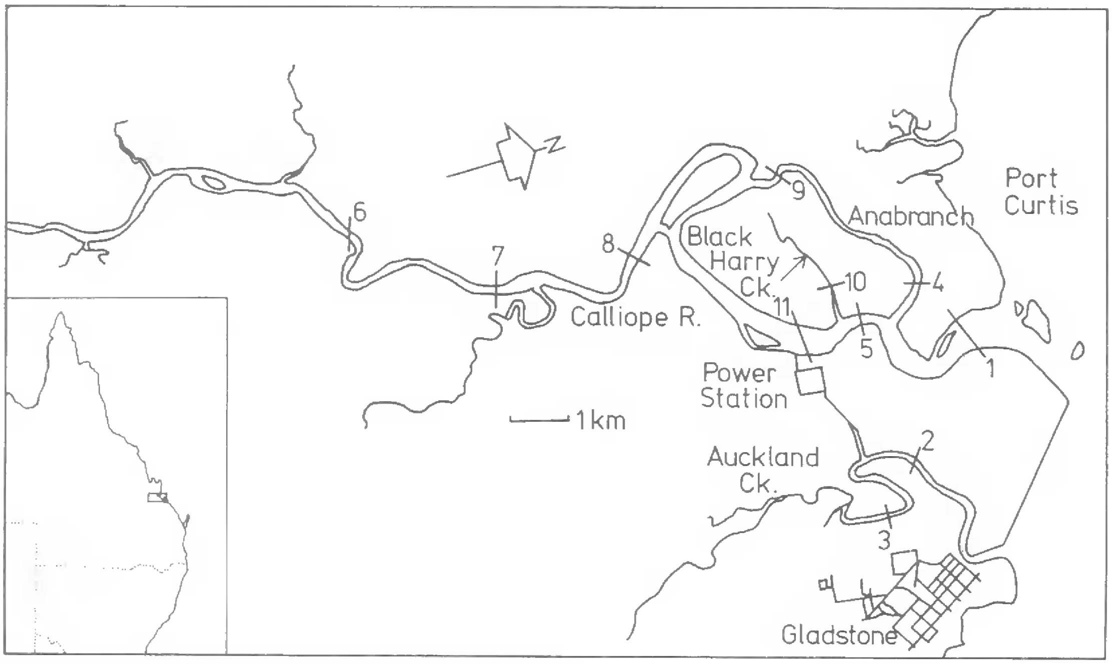

FIG. 1: Map of Study area showing locations of transects 1–11

various sources for the duration of the study period, and these are presented in Fig. 2. These data show cyclic changes in water temperature with an optimal wavelength of 12 months (Saenger et al. 1979), and somewhat less regular changes in salinity and oxygen saturations. A correlation between sharp changes in salinity and dissolved oxygen are also apparent, and the inflow of water rich in detritus is probably involved.

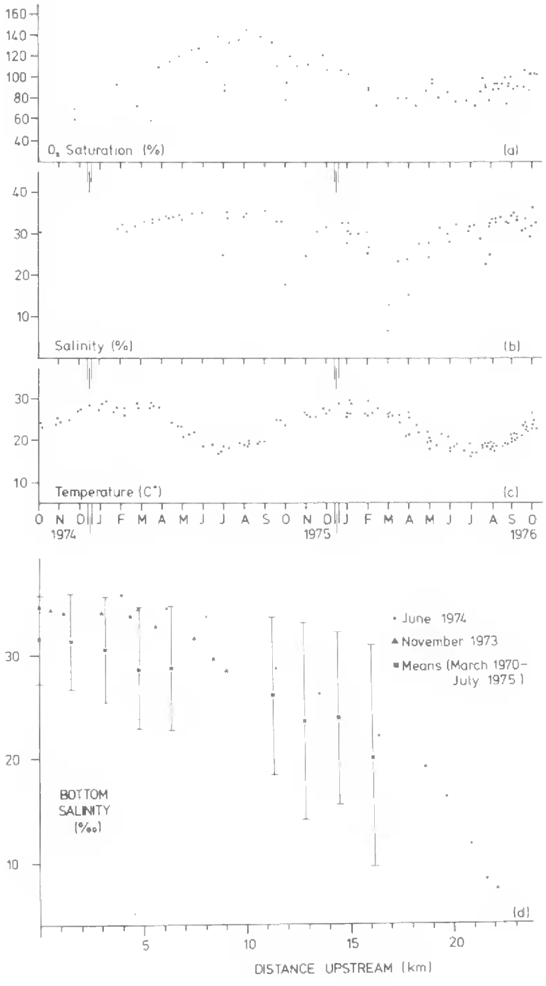

FIG. 2: Physico-chemical parameters of Calliope River; (a) oxygen saturation opposite power station site; (b) salinity opposite power station site; (c) bottom water temperatures from throughout the Calliope River; (d) decreasing salinity in the Calliope River with increasing distance upstream. (Based on data collected (i) by spot readings in the river, (ii) continuous salinity/temperature recorders, (iii) Dr J. Greenwood and (iv) Water Quality Council quarterly surveys).

The bottom sediments of the Calliope River include up to 1·3 m of mud, which covers rock, or overlies sand. The mud generally consists of soft, dark-brown or blue-grey, usually organic, silty clay (Hofmann 1971). The sand is brown to grey, silty, fine to medium grained although occasional coarse deposits are found. Gravel and shell debris occur locally, generally in the deeper channels of the river. The present day stream sediment load of the Calliope River, which drains a hinterland of argillaceous rock (Jardine 1925), is predominantly mud.

Quaternary intertidal mud deposits (predominantly quartzite and albite) overlie most of the Palaeozoic rocks to the east, north and west of the power station site (Hofmann 1971). The dark-grey to black organic mud includes layers of silt and sand. The bottom sediments of Auckland Creek include sandy clay, silty sand, and gravels in the deeper channels. Auckland Creek does not have an appreciable catchment area or stream sediment load (Hofmann 1971).

Conaghan (1966), who studied the sedimentary processes in Port Curtis, concluded that tidal circulation dominates the hydrographic features of the area. The scouring effects of tidal currents (the tidal range is up to 4·2 m), particularly at ebb tide, maintains a relatively stable balance between deposition and erosion in all tidal channels, including the smaller creeks.

METHODS

SURVEY DESIGN

Eleven transects were selected on the river and creeks (Fig. 1); each transect extends across the river from about 1 m below L.W.M. at each bank. Two transects were on Auckland Creek, one in Black Harry Creek, two on the anabranch of the Calliope River and 6 were distributed along the length of the main course of the Calliope River. Selection of transects was based on their spread along the rivers and the ease with which they could be accurately relocated. Relocation errors are about ± 2 m except at transects 1 and 11, where they are approximately ± 4 m.

At each transect, five equally-spaced stations were sampled using an 0·05 m² Van Veen grab sampler; the duplicate grabs were combined to

TABLE 2: DEPTH, UPSTREAM DISTANCE AND SUBSTRATE TYPE OF INDIVIDUAL SAMPLING SITES, 1–55.

Transect No.	Station No.	Site No.	Depth at low water (m)	Distance upstream (km)	Substrate type
1	1	1	1·6	1·3	Silty sand
1	2	2	1·9	1·3	Silty sand, some clayplug
1	3	3	1·8	1·3	Silty sand, some clayplug
1	4	4	6·1	1·3	Silty sand, some clayplug
1	5	5	5·6	1·3	Silty sand
2	1	6	1·3	2·8	Sandy silt
2	2	7	2·0	2·8	Silt
2	3	8	3·7	2·8	Silt
2	4	9	2·4	2·8	Silt
2	5	10	1·0	2·8	Yellow clay
3	1	11	0·8	5·6	Coarse sand, some gravel
3	2	12	3·1	5·6	Coarse sand
3	3	13	2·8	5·6	Coarse sand
3	4	14	2·3	5·6	Coarse sand
3	5	15	1·3	5·6	Coarse gravel
4	1	16	2·3	3·8	Coarse gravel
4	2	17	5·2	3·8	Coarse gravel
4	3	18	6·6	3·8	Coarse gravel
4	4	19	7·2	3·8	Fine sand
4	5	20	4·1	3·8	Silt
5	1	21	1·3	3·6	Soft mud
5	2	22	8·3	3·6	Sandy mud
5	3	23	8·0	3·6	Muddy sand
5	4	24	8·7	3·6	Fine sand
5	5	25	9·0	3·6	Silt
6	1	26	2·1	15·1	Solt mud
6	2	27	4·1	15·1	Mud
6	3	28	3·9	15·1	Coarse gravel
6	4	29	2·1	15·1	Coarse gravel
6	5	30	1·8	15·1	Coarse gravel
7	1	31	1·5	11·1	Coarse gravel
7	2	32	2·8	11·1	Coarse gravel
7	3	33	3·7	11·1	Mud, some gravel
7	4	34	4·8	11·1	Coarse gravel
7	5	35	2·2	11·1	Soft mud
8	1	36	3·4	8·3	Silty sand
8	2	37	4·6	8·3	Silty sand
8	3	38	4·4	8·3	Silty sand
8	4	39	4·6	8·3	Silty sand
8	5	40	2·0	8·3	Soft mud
9	1	41	0·6	7·1	Silty sand
9	2	42	2·7	7·1	Silty sand
9	3	43	5·8	7·1	Silty sand
9	4	44	4·1	7·1	Mud
9	5	45	1·2	7·1	Soft mud, some detritus
10	1	46	0·7	4·6	Soft mud
10	2	47	1·3	4·6	Mud
10	3	48	2·7	4·6	Mud
10	4	49	2·3	4·6	Mud
10	5	50	0·9	4·6	Mud
11	1	51	4·4	4·6	Coarse shell material
11	2	52	3·9	4·6	Coarse sand
11	3	53	3·6	4·6	Coarse sand
11	4	54	3·1	4·6	Coarse sand
11	5	55	2·2	4·6	Coarse sand

give a total of 0·1 m² sampled at each of 55 sites in all. For each transect and station, data on depth, sediment type and distance upriver are given in Table 2.

SAMPLE TREATMENT

Sampling was carried out at approximately three-monthly intervals as follows: November 1974; March 1975; June 1975; October 1975; February 1976; May 1976 and August 1976. These times are referred to below as T_{1-7} respectively. On all occasions all sites were sampled although at some site-times, no organisms were found (Table 3).

All samples were subsequently sieved through an 8 mm (to break up the sediments) and a 1 mm sieve in the field and that fraction retained by the fine sieve was fixed in 5% formalin/seawater and subsequently transferred to glycerol: water: ethanol (5:25:70 v/v). Seagrasses and algae were blotted dry and weighed. In order to make these weights approximately equivalent to faunal numbers, the weights were multiplied by 10.

TABLE 3: SITE-TIMES AT WHICH NO ORGANISMS WERE FOUND IN THE SAMPLES

Times	Sites
1	24 28 29 30 32 34 50 55
2	11 35 46 48 54
3	9 15 21 23 24 29 49
4	49
5	45
6	—
7	—

Numerous taxonomic problems were encountered while working up the collections and the assistance of many specialists was enlisted (see acknowledgements). Once species had been identified, subsequent identifications were generally made using validated reference material, except in a few difficult groups such as some polychaetes, echinoderms and ascidians.

ANALYSES OF DATA

Initially the data were treated as three-dimensional i.e. time (1–7) × transect (1–11) × station (1–5), or as two-dimensional i.e. time (1–7) × sites (1–55). In addition there was a species dimension of 263 if all species are included. Five different sample parameters (*s* number of species; *n* number of individuals of all species; *G* Gleason diversity; *H'* standardized Shannon diversity to log base 2; *J'* Shannon equitability) were derived from summations involving all species, and five matrices of times × transects × stations were considered.

Classification

For classificatory purposes, the less abundant species — those with less than 5 individuals in the 385 samples — were eliminated. This reduced the species number to 120, and gave a basic matrix for classification of 120 species × 55 sites × 7 times. Five of these species however were subsequently eliminated because they occurred in less than 2 sites.

Classification into species-, time-, and site-groups were thus initially based on 115 species. For further time-group classification, an additional 6 species were eliminated as they occurred only once. Site classification based on 115 species suggested that many species were scattered throughout the different site-groups, and while these species may be important ones, for classificatory purposes they are in the nature of 'background noise'. These species were ignored during the final site classification, leaving a residuum of 72 species for the determination of site-groups; these 72 species represent 88.7% of all individuals collected during this study.

Data transformations were used as follows: Site classification involved use of the $\log_{10}(n+1)$ transformation followed by the 'Bray-Curtis' dissimilarity measure with subsequent group-average sorting. For species, the transformed values were standardized by totals followed by 'Bray-Curtis' dissimilarity and group-average sorting as before. Data for times were averaged over the 55 sites and transformed by $\log_{10}(n+1)$, and then classified using 'Bray-Curtis' dissimilarity and group-average sorting.

Periodicity

Analyses of periodicity followed the iterative technique described in Saenger et al. (1979) and Stephenson and Burgess (in press). It consists of running the generalized equation,

$$Y = \tfrac{1}{2}A^{\circ} + A\cos\left(\frac{2\pi t}{T}\right) + B\sin\left(\frac{2\pi t}{T}\right)$$

where Y is the recording of a species at time t,
T is the wavelength of the curve,
$\tfrac{1}{2}A^{\circ}$ is the estimated midpoint of the curve,
A is the contribution of the cosine component,
B is the contribution of the sine component.

through a series of wavelengths, and determining the proportion of the total sum of squares accounted for by the regression (R^2). If the selected wavelength is the predominant one in the system, then R^2 will be maximal.

TABLE 4: Faunistic Composition of the Calliope River and Auckland Creek Macrobenthos.

Phylum and class	Total No. individuals	No./Station	Total No. of species
Thallophyta	2·71*	49**	14
Anthophyta	7·33*	133**	1
Sub-totals	10·04*	182**	15
Coelenterata			
Anthozoa	11 (0·1%)	0·2	2 (0·8%)
Pennatulida	2 (0·1%)	0·1	2 (0·8%)
Alcyonaria	3 (0·1%)	0·1	1 (0·4%)
Nemertea	29 (0·4%)	0·5	1 (0·4%)
Echiura	9 (0·1%)	0·2	1 (0·4%)
Platyhelminthes			
Turbellaria	11 (0·1%)	0·2	2 (0·8%)
Bryozoa	4 (0·1%)	0·1	1 (0·4%)
Annelida			
Polychaeta	1455 (19·0%)	26·5	76 (30·6%)
Oligochaeta	1 (0·1%)	0·1	1 (0·4%)
Mollusca			
Pelecypoda	1927 (25·2%)	35·03	33 (13·3%)
Gastropoda	521 (6·8%)	9·47	17 (6·9%)
Scaphopoda	12 (0·2%)	0·2	1 (0·4%)
Arthropoda			
Crustacea	2150 (28·1%)	39·09	91 (36·7%)
Pycnogonidae	7 (0·1%)	0·1	3 (1·2%)
Echinodermata			
Ophiuroidea	399 (5·2%)	7·25	7 (2·8%)
Holothuroidea	1023 (13·4%)	18·6	1 (0·4%)
Phoronida	1 (0·1%)	0·1	1 (0·4%)
Chordata			
Ascidiaceae	16 (0·2%)	0·3	3 (1·2%)
Pisces	59 (0·8%)	1·07	4 (1·6%)
Sub-totals	7640	138·9	248
Total			263

* as grams
** as mg/station

TABLE 5: Numerically Most Abundant Benthic Species.

Code No.	Species	Total No. of Individuals		% of Site-times at which species found
	POLYCHAETA		% of all polychaetes in surveys	
76	*Glycera americana*	186	12·8	27·3
86	*Leitoscoloplos* sp. nov.	54	3·7	3·6
95	*Nephtys mesobranchia*	70	4·8	9·6
98	*Ophelina* sp.	54	3·7	8·8
104	*Prionospio* sp.	58	4·0	6·2
111	*Scoloplos implex*	111	7·6	3·9
124	*Magelona dakini*	110	7·6	7·8
	CRUSTACEA		% of all crustaceans in surveys	
	BRACHYURA			
194	*Paracleistostoma mcneilli*	76	3·5	5·7
	AMPHIPODA			
238	*Dryopoides* sp.	228	10·6	8·3
239	*Ericthonius* sp.	180	8·4	3·6
242	*Grandidierella* sp. I	51	2·4	4·4
243	*Grandidierella* sp. II	143	6·7	11·4
	TANAIDACEA			
276	*Apseudes estuarius*	649	30·2	4·7
	MYSIDAE			
298	*Unident.* sp. IV	62	2·9	1·0
	ISOPODA			
302	*Sphaeroma* sp.	58	2·7	3·4
	MOLLUSCA		% of all molluscs in surveys	
	GASTROPODA			
331	*Nassarius burchardi*	335	13·6	37·4
	BIVALVIA			
356	*Circe cf. australis*	68	2·8	9·1
364	*Gouldia* sp. I	109	4·4	15·1
368	cf. *Laternula* sp.	621	25·2	20·3
371	*Modiolus auriculatus*	109	4·4	7·3
372	*Notospisula parva*	329	13·4	19·2
377	*Solecurtis* sp.	269	10·9	11·7
381	*Tellina* sp.	236	9·6	21·3
	ECHINODERMS		% of all echinoderms in survey	
	OPHIUROIDEA			
405	*Amphiura micra*	365	25·7	8·0
	HOLOTHUROIDEA			
408	*Protankyra verrilli*	1,023	71·9	23·4
	FISH		% of all fish in survey	
	PISCES			
452	*Brachyamblyopus cf. urolepis*	53	89·8	11·2

RESULTS

Faunistic Composition

A total of 263 taxa were recorded in the survey although some are probably oversplit (e.g. *Magelona* and MAGELONIDAE sp. I) whilst others require subdivision (e.g. *Squilla, Alpheus).* All species are listed in the Appendix together with the code numbers used throughout.

Of the 263 taxa, 15 were seagrasses or algae (Table 4). Amongst the faunal taxa, 36.7% were crustaceans, 30.6% polychaetes, 20.6% molluscs and 12.1% belonged to other groups (Table 4). In terms of the 7640 individuals recorded, 28.1% were crustaceans, 32.2% molluscs, 19.0% polychaetes and 20.7% belonged to other groups (Table 4). The most numerous species within these categories are listed in Table 5.

Several new species have been found in this study, including the polychaete *Nephtys mesobranchia* Rainer and Hutchings (1977) and the pycnogonid *Propallene saengeri* Staples (1979). In addition, several new Australian records were established including significant extensions to the previously known ranges; these species are indicated in the Appendix.

By summating the station data for each transect in the main channel of the Calliope River, it is possible to obtain an overall view of the upstream distribution of organisms. Two trends are apparent in this data; Fig 3a shows that the total number of species recorded at each transect decreased with increasing distance upstream. Presumably this reflects the gradual loss of marine species with increasing freshwater influence. The second trend (Fig. 3b) is in the number of organisms per m², and shows an initial decrease — minimum approximately 8 km upstream of the mouth — followed by a rapid increase upstream of this point. This upstream increase is largely due to a few species of amphipods, *Apseudes estuarius*, and the mussel *Modiolus auriculatus*, suggesting that these species reach large numbers in the presence of a marked freshwater influence.

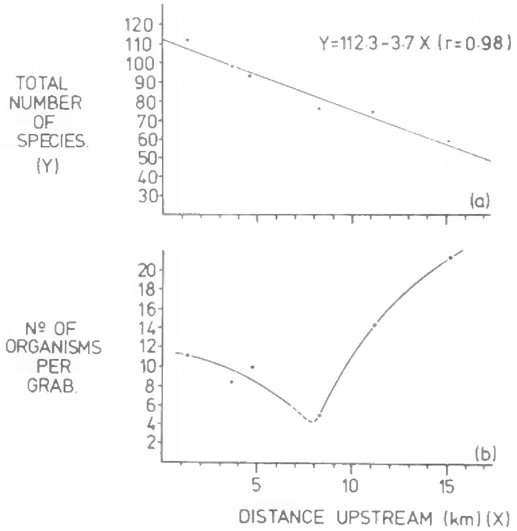

FIG 3: Upstream distribution of species and individuals of all species in the Calliope River.

MEAN SAMPLE PARAMETERS

The meaned data from various groupings of samples are given in Table 6. Overall means were: *s* 6·08; *n* 20·08; *G* 1·86; *H'* 1·76 and *J'* 0·71. From each row, the mean sum of squares (mss) was obtained (Table 6) and these indicate that there is much greater heterogeneity between times than between transects, and between transects than between stations. It is also evident that there is a hierarchy of heterogeneity between the parameters with $n>s>G>H'>J'$. The main cause of times heterogeneity is the high value of all parameters (except *J'*) at time T_7 (August 1976), contrasted with the low values in T_2 (March 1975). The likely importance of this is discussed later.

TABLE 6: MEANS OF THE 5 SAMPLE PARAMATERS (*s, n, G, H'* AND *J'* (IN THE 7 TIMES, 11 TRANSECTS AND 5 STATIONS. (ALSO MEAN SUM OF SQUARES VARIATION IN EACH ROW.)

	TIMES 1	2	3	4	5	6	7	MSS
s	3·36	2·16	4·04	5·31	4·87	7·40	15·44	16·905
n	7·56	3·78	8·25	12·04	12·47	20·05	76·38	550·662
G	1·25	0·78	1·48	1·86	1·66	2·27	3·71	0·759
H'	1·33	0·80	1·51	1·80	1·75	2·23	2·88	0·378
J'	0·69	0·51	0·68	0·77	0·78	0·80	0·77	0·009

	STATIONS 1	2	3	4	5	MSS
s	6·10	6·32	6·65	5·47	5·87	0·160
n	20·43	17·69	21·74	19·58	20·95	1·919
G	1·84	2·05	1·99	1·65	1·76	0·021
H'	1·79	1·97	1·79	1·53	1·72	0·020
J'	0·73	0·79	0·72	0·64	0·68	0·003

	TRANSECTS 1	2	3	4	5	6	7	8	9	10	11	MSS
s	7·49	6·49	6·00	7·00	7·20	5·60	5·54	4·71	6·97	3·89	6·03	1·114
n	23·66	21·23	21·54	12·74	16·94	43·20	28·86	9·77	15·57	7·83	19·51	88·059
G	2·20	1·97	1·88	2·27	2·34	1·32	1·52	1·56	2·19	1·43	1·78	0·120
H'	2·06	1·83	1·67	2·09	2·12	1·29	1·53	1·61	2·12	1·37	1·67	0·084
J'	0·78	0·75	0·73	0·81	0·77	0·51	0·64	0·69	0·81	0·66	0·68	0·007

SITE CLASSIFICATION

Classifying the 55 sites using 72 species, the sites dendrogram (Fig. 4) was resolved into 9 site-groups; their topographic coherence is shown in Fig. 5 while their depths, substrate types and their position in the river are given in Table 7.

Two site-groups (III, V) consist of a single site respectively; while site-group V is not easy to reallocate, site-group III could be easily fused with site-group IV but it has been retained separately because of the presence of characteristically high frequencies of the isopod *Sphaeroma* and the bivalve *Circe* cf. *australis*.

SPECIES CLASSIFICATION

Species classification using 115 species gave 10 species-groups which could be characterized broadly as 'widespread', 'upstream' or 'downstream'. Perusal of a two-way coincidence table of species-groups in sites showed however that many species were scattered throughout various sites

TABLE 7: ABIOTIC CHARACTERIZATION OF SITE-GROUPS.

Depth	Upstream	Downstream				
	Sand/gravel	Mud	Coarse Sand	Fine Sand	Sandy Mud	Sand/Mud/Gravel
Shallow <2 m		IX				
Intermediate 2–4 m	II	IV	V	VI	VII	
Deep >4 m		III		I		VIII

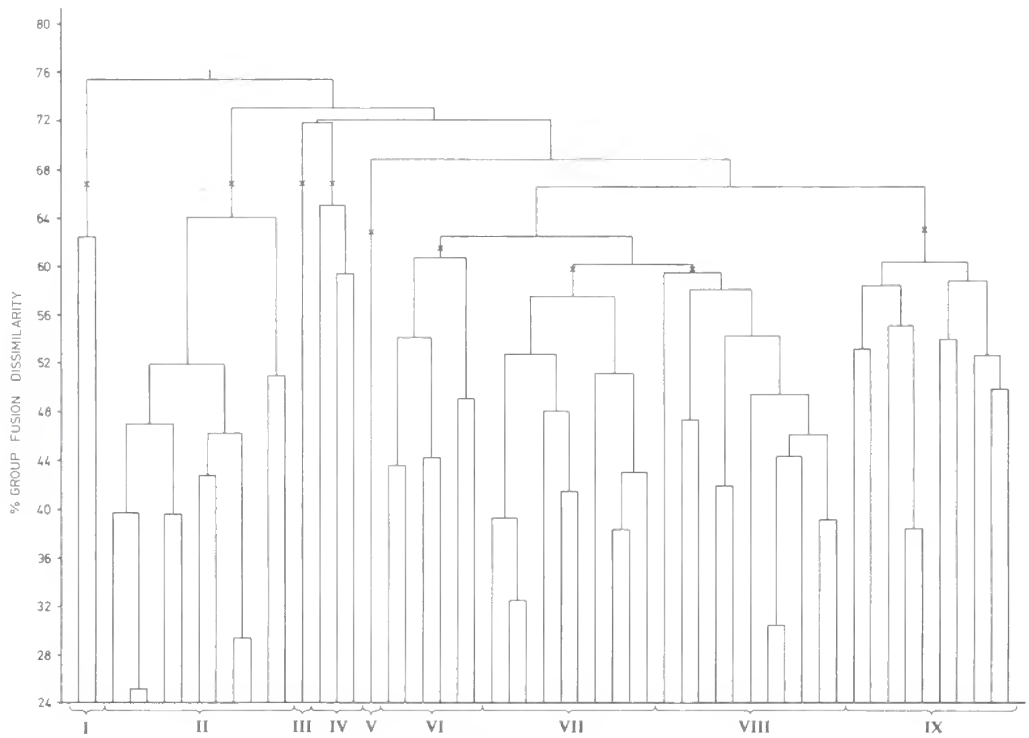

FIG. 4: Dendrogram of site-groupings using 72 species. (X) indicates site-groups accepted.

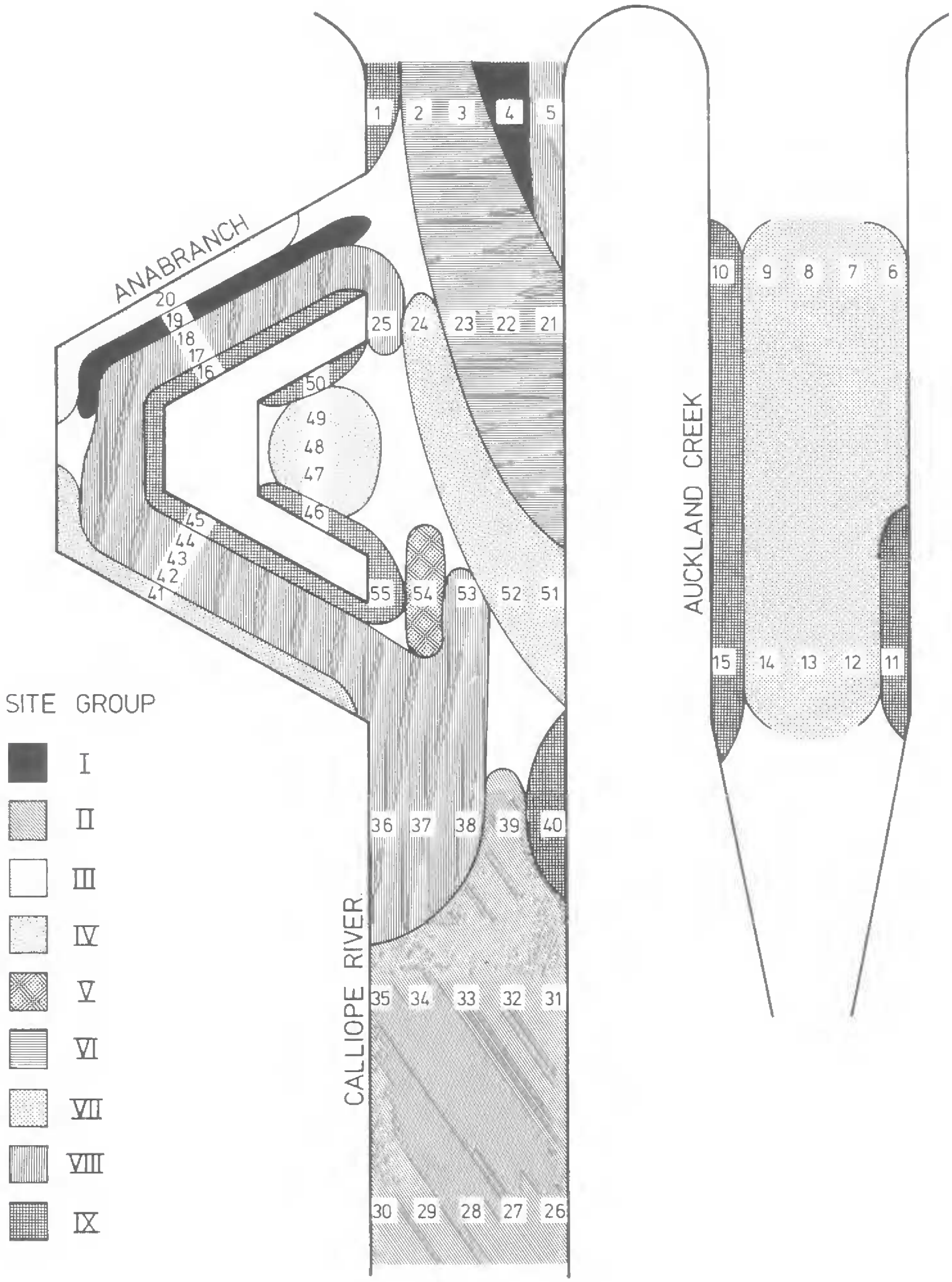

FIG. 5: Schematic representation of the distribution of site-groups I–IX together with the individual sites.

and only 39 species conformed at an equivalent to the 0·10 probability level, when using the pseudo-F test (Stephenson and Campbell 1977) with log transformed data.

Reclassification using only 72 species resulted in 18 species-groups but again, little conceptual insight was gained.

Since the site classification made good topographic and sedimentary sense, the 115 species were classified by using the species occurrences after standardization by the total number of occurrences (log transformed) within the already established site-groups. Classification of these data gave 14 species-groups (Fig. 6) which were accepted as forming more or less natural units (Table 8).

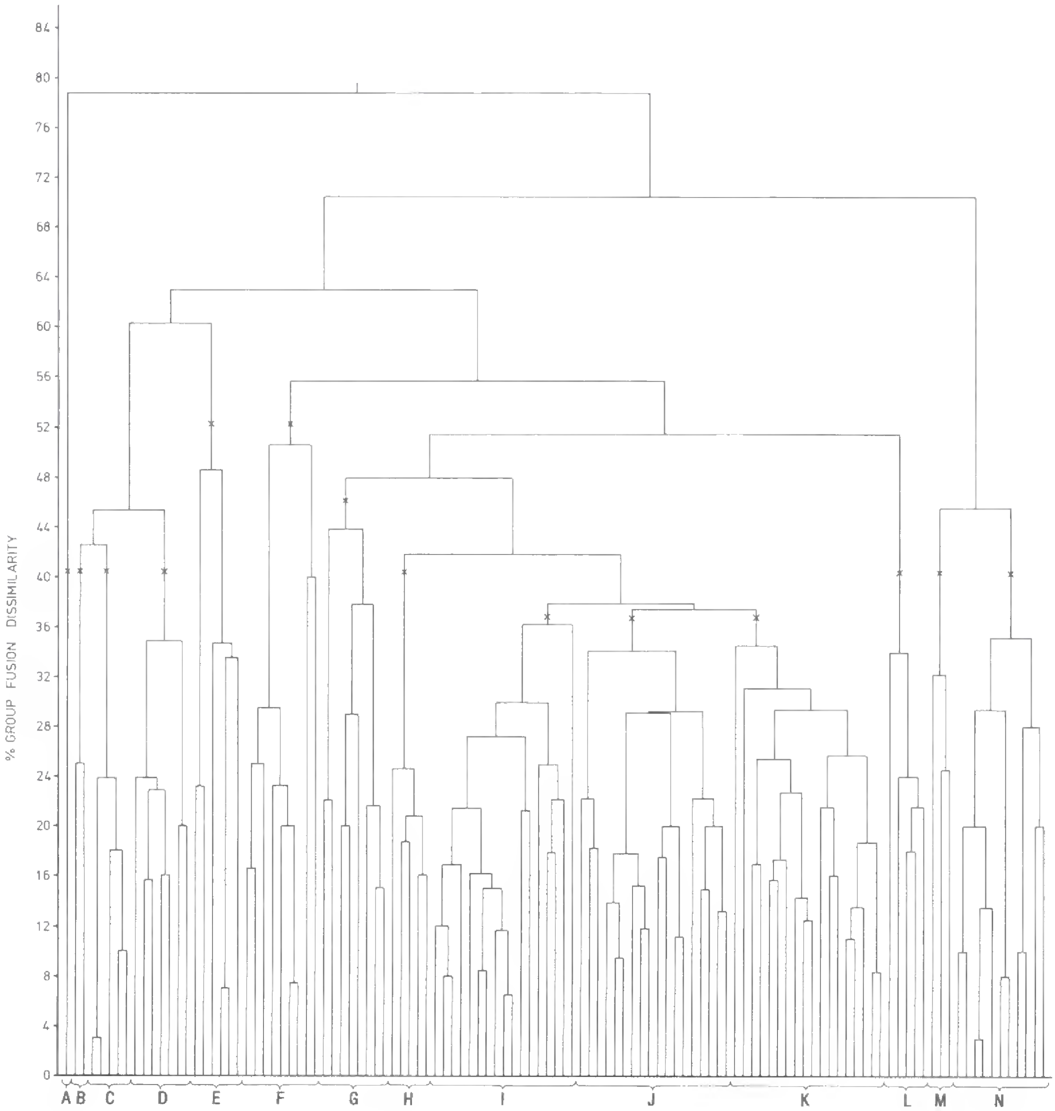

FIG. 6: Dendrogram of species-grouping using 115 species. Crosses indicate species-groups accepted. The individual species comprising these species-groups are given in Table 8.

TABLE 8: INDIVIDUAL SPECIES (BY CODE NUMBER) IN SPECIES-GROUPS A–N AS ACCEPTED IN DENDROGRAM (FIG. 6).

Species Group	Species Composition
A	427
B	197 334
C	51 88 188 327 330
D	79 86 177 187 194 229 298
E	26 69 75 90 303 311
F	67 113 114 115 136 142 156 157 277
G	102 109 122 236 295 312 332 401
H	78 100 130 134 336
I	66 87 95 124 133 140 153 238 242
	243 331 368 369 372 381 403 452
J	32 46 76 82 89 91 98 104 105
	151 159 206 301 333 339 364 377 408
K	77 96 119 123 160 185 244 251 281
	286 287 294 352 356 365 366 380 405
L	3 234 237 378 426
M	74 302 371
N	56 85 101 111 180 183 239 241 247
	276 362

TABLE 9: MEAN PERCENTAGES OF SPECIES - GROUPS IN SITE - GROUPS

Species Group	Site - group								
	I	II	III	IV	V	VI	VII	VIII	IX
A	0	0	0	0	0	0	0	**100**	0
B	0	0	0	0	**12·5**	0	0	**25·0**	**62·5**
C	0	0	0	1·8	0	10·8	**20·0**	0	**67·4**
D	0	**26·0**	6·7	2·9	0	1·3	9·4	8·0	**45·7**
E	4·5	1·7	0	**12·7**	4·2	**40·7**	5·0	0	**31·5**
F	3·9	5·1	2·8	0·7	7·9	10·4	**42·6**	1·6	**25·4**
G	6·6	3·8	3·3	3·8	0	**31·0**	**12·0**	**39·6**	0·8
H	0	10·4	0	7·0	2·4	11·6	**47·6**	**19·8**	1·0
I	2·6	**22·6**	2·6	3·5	0·4	6·9	**17·5**	**28·8**	**15·1**
J	5·6	5·9	0·8	1·3	2·4	**14·4**	**26·0**	**19·1**	**24·7**
K	6·0	4·1	1·4	0·5	0·6	**10·7**	**29·4**	**39·1**	8·4
L	**25·8**	5·0	0	0	0	**12·8**	0	**38·6**	**17·8**
M	5·0	**41·7**	6·0	6·0	0	7·7	0	**22·3**	11·3
N	0	**73·3**	0	0	0	8·2	7·1	8·3	3·2

SPECIES-GROUPS IN SITE-GROUPS

From the species and site classifications, a coincidence table was prepared using the means of species-groups proportions within site-groups (Table 9); heavy type has been used for values greater than 12%. From this table it is readily recognizable which species-groups characterize which site-groups, and which site-groups are the focus of a species-group. For example the species-groups characterizing the most upstream site-group (II) are readily apparent (species-group M and N), while Table 8 allows the individual species in these species-groups to be identified by code number.

TABLE 10: CHARACTERIZATION OF SITE-GROUPS I – IX

Site Groups	Mean Distance Upstream (km)	Predominant Substrate	Mean Depth (m)	Total No. Species	Flora (mg/m^2)	Fauna (N/m^2)	H'	G	J'	Characterizing Species-groups
I	2·6 ± 1·8	Sand	6·7 ± 0·8	59	157	92·1	2·01	2·09	0·88	(+)L (–)A,B,C,D,H,N
II	12·7 ± 2·5	Sand + Gravel	3·1 ± 1·2	99	5	332·7	1·37	1·36	0·57	(+)D,I,M,N (–)A,B,C
III	3·8	Mud	4·1	32	71	122·9	1·74	1·81	0·74	(+) nil. (–)A,B,C,E,H,L,N
IV	4·6	Mud	2·1 ± 0·7	42	152	46·2	1·15	1·24	0·59	(+)E (–)A,B,L,N
V	4·6	Gravel	3·1	27	0	118·6	1·25	1·38	0·45	(+)B (–)A,C,D,G,L,M,N
VI	3·4 ± 2·1	Sand + Mud	3·7 ± 3·5	113	955	143·1	2·06	2·28	0·79	(+)E,G,J,K,L (–)A,B
VII	4·1 + 1·3	Mud + Sand	3·5 ± 2·1	122	3	225·1	1·83	2·02	0·78	(+)C,F,G,H,I,J,K (–)A,B,L,M
VIII	5·8 ± 2·4	Sand + Mud + Gravel	5·0 ± 1·8	162	51	170·0	2·13	2·30	0·79	(+)A,B,G,H,I,J,K L,M (–)C,E
IX	4·8 ± 2·0	Mud	1·4 ± 0·6	128	713	171·1	1·71	1·71	0·70	(+)B,C,D,E,F,I,J,L (–)A

Not only positive but also negative characterizations can be seen (Table 9) and these have been used to give an overall characterization of the site-groups (Table 10).

TIMES CLASSIFICATION

Results of the times classification using 109 species are shown in Fig. 7. The times dendrogram can be accepted at either a 2-group level or a 4-group level; the former splits the early times (T_{1-5}) from later times (T_{5-7}) while the latter gives T_2, $T_{1,3,4,}$ T_5 and T_{6-7}.

Species classification based on times gave 17 species-groups; most of these were sequential groups. Two species-groups emerged which were present throughout the period with the exception of the two later summer times (T_2 — March 1975 and T_5 — February 1976): Species-group A contained only one species, the bivalve *Solen correctus*; species-group B contained the following 10 species — 98, 113, 157, 187, 188, 242, 244, 330, 366 and 401.

Pseudo-F tests of conformity of species to the two levels of time-groupings were performed using a conformity level equivalent to 0·10. Sixty-two species failed to conform to either grouping, and it appears that the time-groupings are partly sequential and partly seasonal.

Intertime dissimilarities are high; the lowest is at approximately 27% while the highest fusion is at approximately 67% dissimilarity. This suggests that either times were too distantly spaced for clear trends to show in the data, or that seasonal differences overlie a non-seasonal trend. On the basis of at least two seasonal species-groups and of cyclical analyses, the latter alternative appears to be the correct one, and no further time-classifications were undertaken.

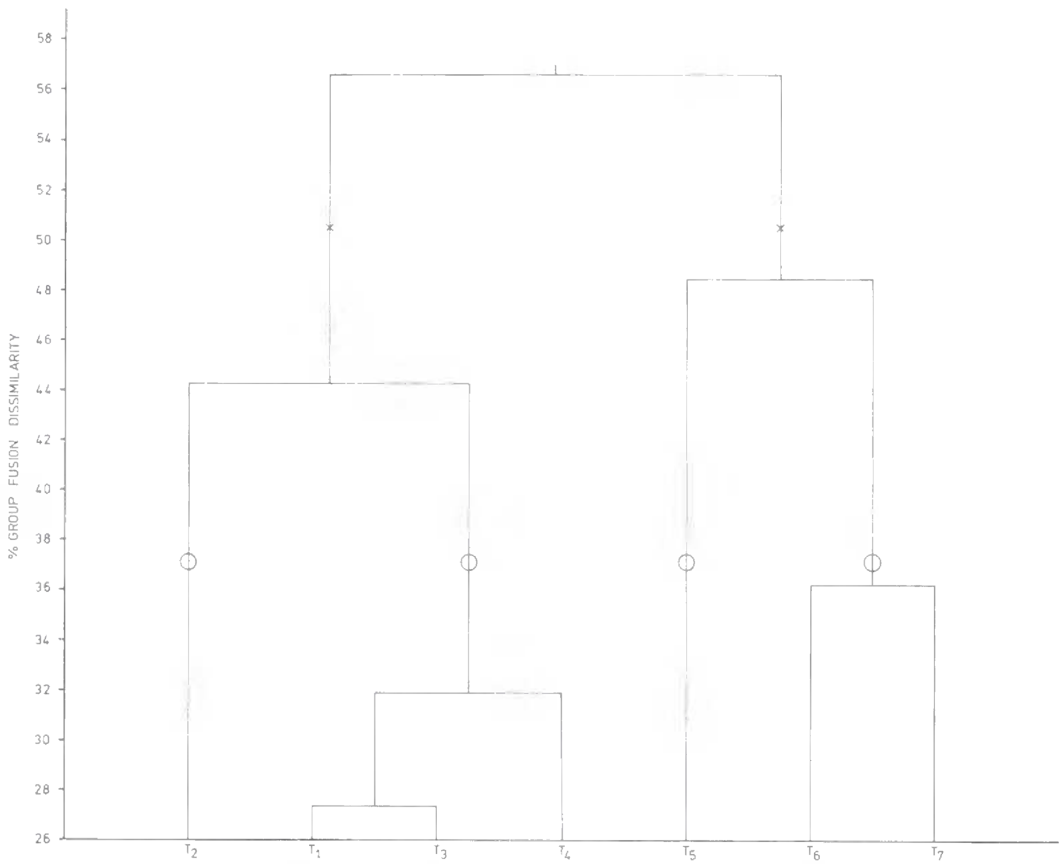

FIG. 7: Dendrogram of time-groupings using 107 species. Circles and crosses indicate the alternate 2-group or 4-group level of acceptance.

SEASONALITY

Because of the low and scattered recordings of many individual species, no attempt was made to subject individual species to cyclic analyses after non-cyclic components had been identified. However two-stage regressions were determined for the summated data.

One stage regressions were performed between times (in months) and the summated values of s, n, H', G and J'. Linear, power curve fit, exponential logarithmic regressions were calculated and significant regressions are given below, and superimposed on Fig. 8.

s, linear, $s = 5{\cdot}25\,t + 28{\cdot}8 \quad r^2 = 0{\cdot}80$

n, exponential, $n = 187\,e^{0.11t} \quad r^2 = 0{\cdot}76$

G, linear, $G = 0{\cdot}554\,t + 6{\cdot}70 \quad r^2 = 0{\cdot}87$

It will be noted that the underlying linear trend in the number of species becomes zero at –5·5 months, or approximately April 1974, while G becomes zero at –12.1 months, or approximately October 1973.

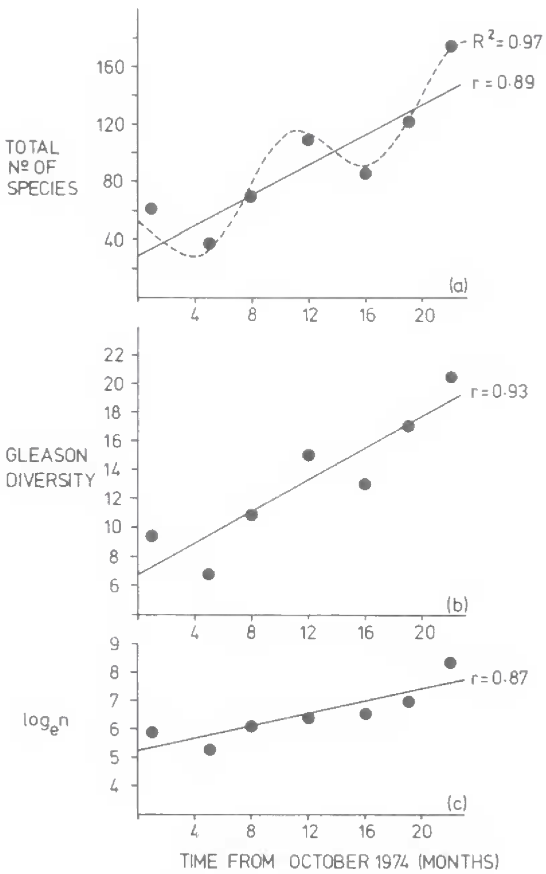

FIG. 8: Changes in parameters, s, G and n summated for all sites, for T_1–T_7

Having identified the non-cyclic components in the data, the residuals were examined for near-annual cycles, using cycles of 9·5 to 13 months in increments of 0·5 months. The values of R^2 (proportion of variance take up) in each case were maximal for cycles of 10·5 months. Considering the total regressions (i.e. linear/exponential plus 10·5 month cycle), R^2 for significance at 0·05 is 0·903 and at 0·01 is 0·967. The total values were: for s 0·974 — highly significant; for n 0·849—not significant; for $G \simeq 1{\cdot}00$ — highly significant.

Although cycles of 10·5 months gave the best fit to the present s values, subsequent sampling since September 1976 indicate that maxima occur annually in September and a 12-monthly period has been used to calculate the constants in the generalized equation,

$$s = \tfrac{1}{2}A^\circ + A\cos\left(\frac{2\pi t}{T}\right) + B\sin\left(\frac{2\pi t}{T}\right)$$

where $\tfrac{1}{2}A^\circ = 3{\cdot}20$

$A = 19{\cdot}28$

$B = -17{\cdot}27$

$T = 12{\cdot}0$

Combining the linear and cyclic components gives,

$$s = 19{\cdot}28\cos\left(\frac{2\pi t}{12}\right) - 17{\cdot}27\sin\left(\frac{2\pi t}{12}\right) + 5{\cdot}25\,t + 32{\cdot}0$$

This curve, superimposed on the data in Fig. 8a shows good agreement, and while reducing the R^2 value from 0·974 to 0·968, it still remains highly significant to the 0·01 level.

DISCUSSION

FAUNISTIC COMPOSITION

The total number of species (263) is less than the total species reported from Moreton Bay (Southern Region — 394 by Stephenson et al. 1974; central region — 182 by Raphael 1974; Middle Banks — 463 by Stephenson et al. 1978) and similar to the number from Port Curtis (251 — Stephenson et al. 1979), but greatly exceeds the number of species so far recorded from southeastern Queensland estuaries (98 — Serpentine Creek, Stephenson and Campbell 1977; 64 — eight estuaries sampled once after the 1974 floods, Campbell et al. 1974).

In other Australian estuarine studies, the following numbers of macrobenthic species have been recorded: 55 — Blackwood River Estuary, W.A. (Hodgkin 1978); 74 — Wallis Lake, N.S.W. (Hutchings et al. 1978); 158 — Careel Bay, N.S.W. (Hutchings and Recher 1974); 246

— Port Phillip Bay, V. (Poore and Kudenov 1978) and 571 — Westernport Bay, V. (Coleman et al. 1978).

In terms of the numbers of organisms per square metre, the benthos of the Calliope River and Auckland Creek is compared with other southeastern Queensland estuaries (Table 11). The large numbers of *Apseudes estuarius* as found in Ninghi, Cabbage Tree and Serpentine Creeks (Campbell et al. 1974; Stephenson and Campbell 1977) have not been observed. Classification of species-groups in site-groups indicated that an 'upstream' community exists in the Calliope River, of which *A. estuarius* is a predominant component; it is thus possible that sampling further upstream than at present may have resulted in higher numbers of individuals per square metre.

Site/Species Classification

The classification of sites using their biotic composition gave site-groups which were easily characterized abiotically (Table 7), and it indicates that sites can be grouped according to their upstream/downstream position, the sediment type and the depth below low water. Classification of species using their standardized occurrences within site-groups, enabled site-groups to be characterized by the presence or absence of certain species-groups (Table 10).

TABLE 11: Numbers of Benthic Organisms per M² Recorded from Queensland Estuaries.

System	n/m²
Calliope River*	0 – 3,540
Auckland Creek*	0 – 1,950
Noosa River	80 – 6,080
Maroochy River	40 – 6,240
Mooloolah River**	463 – 6,481
Ninghi Creek	100 – 15,840
Caboolture River	200 – 11,680
Pine River	340 – 8,660
Cabbage Tree Creek	520 – 33,140
Serpentine Creek***	132 – 14,128
Logan River	20 – 3,060
Coomera River	140 – 1,360
Nerang River	0 – 360

* Present survey
** Saenger unpubl. data
*** Stephenson and Campbell, 1977
Other data based on Campbell et al, 1974

A point that merits emphasis is that with the exception of the upstream areas, the shallow-water and deeper-water biotas at a given distance upstream were quite different; a similar pattern was observed in Serpentine Creek (Stephenson and Campbell 1977). One obvious implication of this finding in relation to baseline benthic surveys is that to adequately sample an area, across-river transects should be used.

Times Classification/Periodicities

Times classification showed high times dissimilarities; initially this suggested that sampling times were too infrequent; however two times showed low values of s and n (T_2 and T_5), both were in late summer and both lacked two times-based species-groups; this suggests a seasonal component. Cyclic analyses of summated parameters confirmed this but indicated that an underlying non-cyclic trend was also present. The underlying linear trend was zeroed at $-8{\cdot}8$ months i.e. January 1974, using the average estimate from s and G.

December 1973 and January 1974 were particularly wet months with unusually heavy rainfall and river flow rates (Table 12), and extensive flooding occurred during this period. In fact on the 20 December 1973, a flow rate of 172,000 megalitres was recorded for the preceding 24-hour period; this 24-hour flow rate is comparable to the mean annual flow rate of normal years (Table 1). In view of this flooding, it became apparent that the benthic data could be best interpreted as a recolonization situation following a 'catastrophic' disturbance, and a model is proposed.

TABLE 12: Gladstone Rainfall and Calliope River Discharges During October 1973 to May 1974.

Month	Monthly Rainfall (mm)*	Monthly River Discharge (megalitres)**
October	43	2,065
November	127	4,751
December	433	401,863
January	640	254,718
February	43	31,652
March	38	8,590
April	29	5,051
May	27	3,514

* Supplied by Department of Meteorology
** Supplied by Water Resources Council of Queensland, from Castlehope Measuring Station.

RECOLONIZATION MODEL

It is postulated that the intense flooding of December–January 1974 led to a more or less complete removal of the benthic fauna as a result of the combination of reduced salinity, physical scouring of the estuary and reduced oxygen levels. These factors have been identified as reducing the benthos elsewhere (Stephenson et al. 1977; Stephenson et al. 1979; Rosenberg 1977; Boesch et al. 1976).

On returning to normal conditions, recolonization would commence. Evidence of recolonization comes from a superficial survey carried out in November 1973 (before flooding) near the power station site, which revealed 44 benthic species (A. Maluish unpubl. data). Another survey, during which 3 sites were sampled near the power station in April 1974 (after flooding), revealed 'no organisms where these would have been expected' (B. Campbell pers. comm.).

The present data suggest that the re-appearance of species is more or less linear over a period of 29 months (Fig. 8a) while the numbers of individuals of all species increase logarithmically (Fig. 8c) during this period. Wolff et al. (1977) followed the colonization of a newly-formed seawater lake for 4·5 years and found that the numbers of individuals increased logarithmically over the entire 4·5 years. A linear increase in the number of species was found over the initial 27 months, but after this time, the number of species did not increase further.

It could be expected that after a massive disturbance, opportunistis benthic species would be the initial recolonizers (Grassle and Grassle 1974; Boesch et al. 1976; Rhoads et al. 1978) with other species reappearing later. The cumulative number of species recorded at various times (Fig. 9) during the study indicates that new species arrived throughout the study, even though the cumulative number at each transect approaches a maximum (Fig. 9). This in turn suggests that genuine changes (as distinct from sampling inadequacies) in the species composition occurred during the 20 months of the study.

In terms of the time scale involved, recolonization after 'catastrophic' and 'seasonal' events must be distinguished. Recovery after seasonal disturbance (e.g. freshwater inflow, high temperatures etc.) seems to occur in approximately 3 months in the present study area (Fig. 8a). In Port Curtis, seasonal recovery occurred after 2–3 months (Stephenson et al. 1979); in a west African estuary a period of 1–2 months was observed (Sandison and Hill 1959) while in a Dutch estuary, seasonal recovery occurred at 2–3 months (Wolff et al. 1977).

Recovery from non-seasonal 'catastrophic' events takes longer and depends on the severity of the disturbance: MacGinitie (1939) reports recolonization after flooding was completed in 9 months; Kaplan et al. (1975) found that the benthos of a dredged channel had not recovered after 11 months; Stephenson et al. (1977) found general recovery 13 months after flooding in Bramble Bay, Queensland; Rhoads et al. (1978) found that colonization of spoil dumps required 1·5–2 years; Watson (1973) estimated that recovery of the benthos after pipeline dredging in Port Phillip Bay, Victoria, would be complete within 2 years; Boesch et al. (1976) found that the benthos had not recovered from the effects of a tropical cyclone after 2·5 years; Wolff et al. (1977) found that species numbers approached a maximum in a new seawater lake after 2·5 years. In the present study, the number of species has not approached a maximum within 29 months after severe flooding (Fig. 8a and 9), although preliminary analyses of subsequent survey data (T_8 — November 1976 to T_{18} — July 1979) suggest that recovery was more or less complete after 5 years.

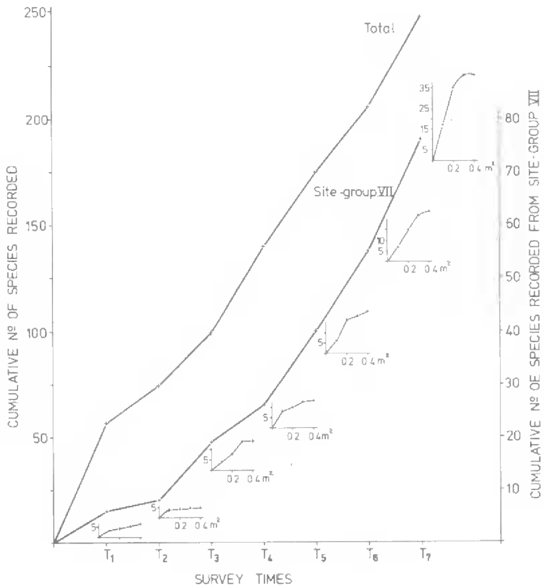

FIG 9: Cumulative number of species recorded for all site-groups and for site-groups VII. Species-area curves for catches at site-group VII are also shown.

While the present model, like all models, has tentative aspects, the data summarized in Figs. 8 and 9 show that the 'pre-thermal' situation is not a stable one, and that progressive changes are occurring. Since these can be expected to continue to occur, two elements are likely to interact during the 'post-thermal' times i.e. recovery from flooding and thermal effects. It will be essential to allow for the former in assessing the latter.

ACKNOWLEDGMENTS

We thank the various Specialists who have grappled with the taxonomic problems; these include Dr P. Hutchings (Polychaetes), Dr W. Ponder (Molluscs), Mr R. Burns (Opisthobranchs), Mr R. Monroe (Amphipods), Mr P. Davie (Brachyurans), Dr P. Mather (Ascidians), Dr D. Hoese (Fish), Dr P. Alderslade (Octocorallia), Mr D. Staples (Pycnogonids), Dr S. Edmonds (Echiura, Sipunculida), Dr L. Cannon (Platyhelminthes), Dr F. Rowe (Echinoderms), Dr A.J. Bruce (Carids), Mr M. Johnston (Cumaceans) and Dr J. Ross (Bryozoans).

We also thank the Department of Meteorology for the meteorological data and the Water Resources Council of Queensland for the Calliope River flow data.

Finally we thank our colleagues in the Q.E.G.B. for their generous and varied assistance, particularly Mr J. Ewald for his constructive advice and comments; and the members of the Environmental Study Advisory Committee for their continual constructive review.

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APPENDIX
RIVER BENTHOS SPECIES LIST WITH CODE NUMBERS

(* indicates new species or major extension of range)

ALGAE
1 *Champia parvula*
2 *Enteromorpha clathrata*
3 *Heterosiphonia multiceps*
4 *Laurencia obtusa*
5 *Lophocladia* sp.
6 *Polysiphonia flaccidissima*
7 *Crouania* sp. nov.*
8 *Sporochnus comosus*
9 *Spyridia filamentosa*
10 *Ulothrix* sp.
11 *Callithamnion* sp.
12 *Soliera robusta*
13 *Griffithsia* sp.
14 *Ceramium cliftonianum*

SEAGRASSES
26 *Halophila decipiens*

COELENTERATA
31 ANTHOZOA sp. I
32 ANTHOZOA sp. II
33 *Virgularia gustaviana*
34 *Dendronephtya (Morchellana)* sp.*
35 *Virgularia gracillima*

NEMERTEA
46 Unident sp. I

ECHIURA
51 ECHIURIDAE sp. I

PLATYHELMINTHES
56 Stylochid sp. A
57 Planocerid sp. A

BRYOZOA
61 *Bugula* cf. *uniserialis*

POLYCHAETA
66 *Amaeana trilobata*
67 *Ampharete* sp.
68 *Armandia intermedia*
69 *Branchiomma* sp.
70 *Cirratulus* sp.
71 *Cirriformia* sp.
72 *Capitella* sp.
73 *Coppingeria longisetosa*
74 *Ceratocephala* sp.
75 *Diopatra* sp.
76 *Glycera americana*
77 *Glycera* sp.
78 HESIONIDAE sp. I
79 *Heteromastus* sp.
80 HETERONEREIIDAE sp. I
81 *Harmothoe* sp.
82 *Lysilla apheles*
83 *Lysilla pacifica*
84 *Laonice* sp.
85 *Leitoscoloplos normalis*
86 *Leitoscoloplos* sp. nov.*
87 *Lumbrinereis* sp.
88 *Lepidonotus* sp.
89 MAGELONIDAE sp. I
90 MALDANIDAE sp. I
91 *Mediomastus* sp.
92 *Marphysa sanguinea*
93 *Maldane* sp.
94 NEREIIDAE sp. I
95 *Nephtys mesobranchia**
96 *Notomastus* sp.
97 OPHELIIDAE sp. I
98 *Ophelina* sp.
99 *Owenia fusiformis*
100 *Poecilochaetus serpens*
101 *Poecilochaetus* sp.
102 *Pista pectinata*

103 *Pista* sp. nov.*
104 *Prionospio queenslandica*
105 *Polydora* sp.
106 POLYONIDAE sp. I
107 *Phyllodoce* sp. I
108 *Phyllodoce* sp. II
109 *Pectinaria* sp.
110 *Scyphoproctus* sp.
111 *Scoloplos implex*
112 *Scoloplos johnstonei*
113 *Sthenolepis* sp.
114 *Sternaspis scutata*
115 *Stenelais* sp.
116 *Streblosoma amboinense*
117 *Streblosoma* sp.
118 TEREBELLIDAE (s.f. Thelepinae) sp. I
119 *Terebellides stroemi*
120 *Thelepus setosus*
121 *Pseudopolydora kempi*
122 *Onuphis* sp.
123 *Isolda pulchella*
124 *Magelona dakini*
125 *Laonome* sp.
126 *Australonereis ehlersi*
127 SERPULID sp. I
128 *Ancistrosyllis* sp.
129 OLIGOCHAETE sp. I
130 *Cossura* sp.
131 *Aonides* sp.
132 *Eunice* c.f. *australis*
133 *Ceratonereis erythraeensis*
134 *Euclymene* sp.
135 *Mediomastus californiensis*
136 *Scolelepis* sp.
137 *Syllis* sp. I
138 CHAETOPTERIDAE sp. I
139 SABELLIDAE sp.
140 *Spio pacifica*
141 *Ophiodromus* sp.
142 *Syllis* sp. II
150 *Phoronis* sp.

NATANTIA
151 *Alpheus* sp.
152 *Metapenaeopsis* sp.
153 *Parapenaeopsis* sp.
154 *Metapenaeus bennettae*
156 *Lysmata* sp.
157 *Macrobrachium intermedium*
158 *Latreutes mucronatus*
159 *Ogyrides delli*
160 HIPPOLYTIDAE sp. II
162 *Lucifer* sp.

BRACHYURA
176 *Acheus lacertosus*
177 *Australoplax tridentata*
178 *Dorippa astuta*
179 *Dorippa* sp.
180 *Elamenopsis lineata*
181 *Eucrate* sp.
182 *Halicarcinus australis*
183 *Halicarcinus* sp. A
184 *Halicarcinus bedfordi*
185 *Heteropanope* sp.
186 *Hyastenus* sp.
187 *Ilyoplax dentatus*
188 *Ilyoplax orientalis*
189 *Macrophthalmus punctulatus*
190 *Macrophthalmus latreillei*
191 *Matuta* sp.
192 *Neorhynchoplax* sp.
193 *Nursia abbreviata*
194 *Paracleistostoma mcneilli*
195 *Petrolisthes teres*
196 *Petrolisthes* cf. *scabriculus*
197 *Petrolisthes* sp. nov.
198 *Phalangipus* sp.
199 *Pilumnus* sp. A
200 *Pilumnus* sp. B
201 *Pilumnus* cf. *hirsutus*
202 *Portunus pelagicus*
203 *Raphidopus cilatus*
204 *Sesarma semperi longicristatum*
205 *Uca* sp.
206 *Xenophthalmus pinnotheroides*

AMPHIPODA
226 AMPELISCIDAE sp.
227 AMPHIPODA sp. I
228 AMPHIPODA sp. II
229 AMPHIPODA sp. III
230 AMPHIPODA sp. IV
231 AMPHIPODA sp. V
232 AMPHIPODA sp. VI
233 AMPHIPODA sp. VII
234 CAPRELLIDAE sp. I
235 CAPRELLIDAE sp. II
236 *Ceradocus* sp.
237 *Corophium* sp.
238 *Dryopoides* sp.
239 *Ericthonius* sp.
240 *Eriopisa* sp. I
241 *Eriopisa* sp. II
242 *Grandidierella* sp. I
243 *Grandidierella* sp. II
244 *Grandidierella* sp. III
245 *Maera* sp. I
246 *Maera* sp. II
247 *Melita* sp.
248 *Oedicerateda* sp. I
249 *Oedicerateda* sp. II
250 *Paracorophium* sp.
251 *Paraphoxus* sp.
252 *Quadrivisio* sp.
253 AMPHIPODA VIII

OTHER CRUSTACEANS
276 *Apseudes estuarius*
277 *Apseudes* sp. II
278 *Apseudes* sp. III
279 *Tanais* sp.
281 OSTRACODA sp. I
282 OSTRACODA sp. II
285 *Pomacuma australiae*
286 *Dimorphostylis australis*
287 *Eocuma agrion*
288 *Cyclaspis ? usitata*
289 *Campylaspis latidactyla*
294 PAGURIDAE sp. I
295 MYSIDAE sp. I
296 MYSIDAE sp. II
297 MYSIDAE sp. III
298 MYSIDAE sp. IV

ISOPODA
301 *Mesanthura* sp.
302 *Sphaeroma* sp.
303 *Synidotea* sp.
304 *Paracereis* sp.
305 *Eurydice sp.*

STOMATOPODA
311 *Squilla* sp.
312 *Callianassa* sp.
313 *Thalassina anomala*

PYCNOGONIDAE
316 *Propallene saengeri**
317 *Hemichela* sp. nov.*
318 *Anoplodactylus tubiferus**

GASTROPODA
326 *Aglaja* sp. nov.*
327 *Atys* sp.
328 *Bedeva hanleyi*
329 *Cerithideopsilla cingulata*
330 *Haminoea* sp.
331 *Nassarius burchardi*
332 *Nassarius dorsatus*
333 *Nassarius* sp.
334 *Polynices sordida*
335 *Pseudoraphitoma* sp.
336 *Ringicula* sp.
337 *Zafra* sp.
338 *Zeacumantus* sp.
339 *Philine* sp. nov.
340 *Tornatina* sp.
341 *Trinchesia* sp.
342 *Facelinella* sp.

PELECYPODA
351 *Anomia descripta*
352 *Amygdalum* sp.
353 ARCIDAE sp. I
354 *Barnea* sp. I
355 *Barnea* sp. II
356 *Circe* cf. *australis*
357 *Circe* sp. II
358 *Corbula* sp.
359 *Didimacar repeata*
360 *Ennucula* sp.
361 *Ensiculus cultellus*
362 *Fluviolanatus amarus*
363 *Gari lessoni*
364 *Gouldia* sp. I
365 *Gouldia* sp. II
366 *Laternula* sp. I
367 *Laternula* sp. II*
368 cf. *Laternula* sp.
369 *Limaria noverea*
370 *Mactra* sp.
371 *Modiolus auriculatus*
372 *Notospisula parva producta*
373 *Nuculana* sp.
374 *Pharella wardi*
375 *Placamen* sp.
376 *Saccostrea* cf. *cucullata*
377 *Solecurtus* sp.
378 *Solen correctus*
379 *Tapes hiantina*
380 *Tellina semen*
381 *Tellina* sp.
382 *Trisidos tortuosa*
383 VENERIDAE sp. I
384 *Volachlamys singaporinus*
400 *Dentalium* sp.

ECHINODERMATA
401 *Amphioplus personatus*
402 *Amphioplus hastatus*
403 *Amphiura bidentata**
404 *Amphiura leptotata**
405 *Amphiura micra**
406 *Amphiura phrixa**
407 *Amphiura tenuis**
408 *Protankyra verrilli*
409 *Amphiura octacantha**
410 *Amphipholis squamata*

TUNICATA
426 *Ascidia sydneyensis*
427 *Molgula mollis*
428 *Cnemidocarpa etheridgii*
429 *Microcosmus australis*

PISCES
451 APOGONIDAE sp. I
452 *Brachyamblyopus* cf. *urolepis*
453 *Drombus palackyi*
454 *Prionobutis microps*
455 *Favonigobius* sp.